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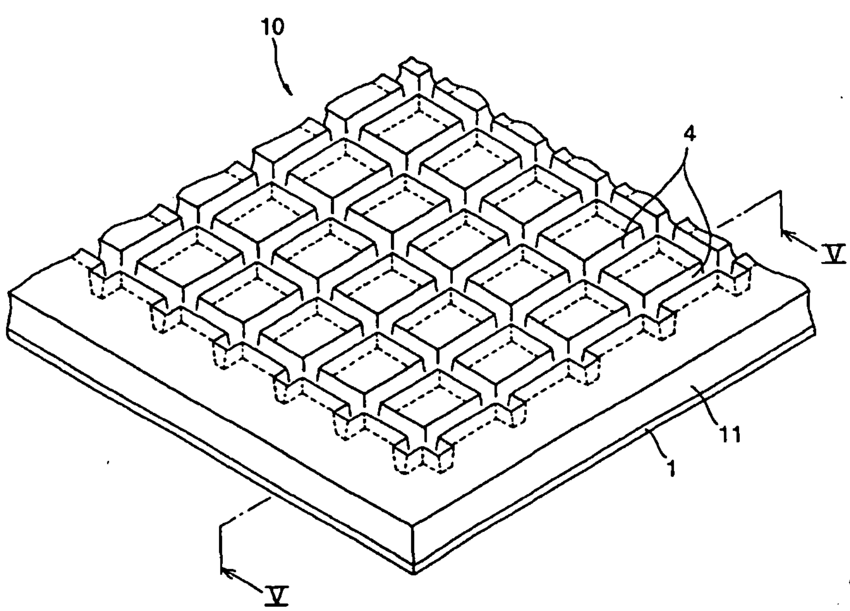
(54) Title: FLEXIBLE MOLD AND METHOD OF MAKING SAME AS WELL AS METHOD OF MANUFACTURING FINE STRUCTURES



(57) Abstract: A flexible mold comprising a support formed of humidity responsive material and a mold layer having groove-pattern of predetermined shape and size on the surface, wherein said predetermined shape and size are given to said predetermined groove-pattern by conditioning the mold after it is released from the metal master pattern in a condition of predetermined temperature and humidity.

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FLEXIBLE MOLD AND METHOD OF MAKING SAME AS WELL AS METHOD OF MANUFACTURING FINE STRUCTURES

Field of the Invention

The present invention relates to mold technology, and more particularly to a flexible mold and a method of making same and a method of manufacturing fine or miniaturized structures. The method of manufacturing fine structures according to the present invention can be advantageously used, for example, for manufacturing barrier ribs on back panel of a plasma display panel.

Background

As is well known, with the advance and development of television technology, display devices using cathode ray tubes (CRTs) have been economically mass-produced. In recent years, however, in place of these displays using CRTs, thin and light weight flat panel display devices have attracted increasing attention as display devices in next generation.

One of the representative flat panel display devices is a liquid crystal display (LCD) device which has already been widely used as a compact display device in a notebook-type personal computer, a cellular telephone, a personal digital assistant (PDA), or other portable electronic information apparatus. On the other hand, as a thin and large-screen-size flat display, a plasma display panel (PDP) is a typical display device, and indeed begins to be used in business and recently also in home as a wall hanging type television screen.

A PDP has the construction as shown schematically in Fig. 1. Although, in the illustrated example, the PDP 50 includes only one discharge cell 56 for display, for the sake of simplicity, it usually includes a multiplicity of small discharge cells for display. More specifically, each discharge

cell 56 for display is defined as surrounded by a pair of glass substrates, that is, a front glass substrate 61 and a back glass substrate 51, which are spaced apart and opposed to each other, and a fine structure of ribs (barrier ribs, sometimes called partition wall or barrier) 54 having a specified shape disposed between these glass substrates. The front glass substrate 61 comprises a transparent display electrode 63 consisting of scanning electrode and sustaining electrode, a transparent dielectric layer 62, and an overlying transparent protective layer 64. The back glass substrate 51 comprises an address electrode 53 and an overlying dielectric layer 52. The display electrodes 63 consisting of scanning electrode and sustaining electrode, and the address electrodes 53 are perpendicular to each other, and are respectively arranged spaced apart in a specified pattern. Each discharge cell 56 for display has a fluorescent layer 55 formed on the interior wall thereof, and has rare gas (for example, Ne-Xe gas) sealed in the inside so as to enable light emitting display by means of plasma discharge between above-mentioned electrodes.

In general, the ribs 54 consist of fine structure of ceramics, and usually, as shown schematically in Fig. 2, are provided together with address electrodes 53 on the back glass substrate 51 in advance to form a back panel for PDP. Since the shape and dimensional precision of the ribs significantly affect the performance of PDP, various improvement have been made on the mold used for manufacturing ribs and on the manufacturing method. For example, there is suggested a method for manufacturing barrier ribs characterized in that metal or glass is used as mold material and coating liquid for forming ribs (partition wall) is disposed between the surface of a glass substrate and the mold material, and that the mold material is removed after the coating liquid is hardened and thereafter the substrate having the hardened coating liquid

transferred thereon is baked (Patent Literature 1). Also, there is suggested a method for manufacturing a substrate for PDP comprising the steps of filling a mixture of ceramic or glass powder with a solvent and a binder consisting of an organic additive into a silicone resin mold having cavities for the partition walls, and joining this mixture integrally to a back panel formed of ceramics or glass (Patent Literature 2). Further, there is suggested a method for manufacturing partition walls comprising the steps of forming a partition wall member having a predetermined softness in the shape of a plate of a predetermined thickness on a surface of a substrate, molding the partition wall member under pressure by a press mold provided with a shape corresponding to the partition wall to be formed, releasing the press mold from the partition wall member, and heat-treating the molded partition wall member at a predetermined temperature (Patent Literature 3).

However, the molds for manufacturing PDPs as disclosed in these patent publications and in other literatures have still some problems to be resolved. That is, due to the mold material used for the manufacture, any of these molds may be subjected to dimensional change from the manufacture to the actual usage especially because of the change of temperature or humidity, and therefore may be unable to provide the intended ribs with high precision. In order to avoid the change of shape and deterioration of dimensional precision, the mold needs to be stored and used in an environment in which temperature and humidity are precisely controlled, and this would inevitably increase labor cost and investment cost.

In manufacturing the back panel for PDP, it is required that the ribs should be provided at specified location with little deviation relative to the address electrodes. This is because the more accurately the ribs are provided at specified location and the higher is the dimensional precision, the more

excellent light emitting display can be achieved in PDP. However, when there is change in the ambient temperature and humidity, the control of dimensions of the mold by adjusting the surrounding temperature and humidity is difficult to be achieved, since the effect on dimensional change of the substrate, change of the viscosity of the coating liquid for forming the ribs, and change in the precision of the rib molding machine cannot be eliminated.

Summary of the Invention

In one aspect of the present invention, there is provided a flexible mold comprising a support formed of a humidity responsible material and a mold layer provided on the support and having a groove-pattern of specified shape and size formed on the surface thereof, characterized in that the specified shape and size are given to the groove-pattern by conditioning the mold at predetermined temperature and humidity after the mold is released from the metal master pattern.

In another aspect of the present invention, there is provided a method of making a flexible mold having a support and a mold layer provided on the support and having a groove-pattern of specified shape and size formed on the surface thereof, comprising the steps of:

forming a layer of photocurable material by coating a photocurable material at a predetermined film thickness on a die having on its surface a protrusion pattern of shape and size corresponding to the groove-pattern of the above-mentioned mold;

laminating a transparent support formed of humidity responsible plastic film on said metal master pattern to thereby form a laminate composed of said metal master pattern, said layer of photocurable material and said support;

irradiating said laminate with light from the side of the

support to thereby cure said layer of photocurable material;

releasing from said metal master pattern said mold layer formed by curing of said layer of photocurable material together with said support; and

conditioning the obtained mold under a condition of predetermined temperature and humidity to thereby adjust shape and size of the groove-pattern on said mold layer.

In still another aspect of the present invention, there is provided a method for manufacturing a fine structure having a protrusion pattern of specified shape and size on the surface of a base board, comprising the steps of:

providing a flexible mold which comprises a support formed of a humidity responsible material and a mold layer provided on said support and having a groove-pattern of shape and size corresponding to said protrusion pattern formed on the surface thereof, and in which the shape and size of said groove-pattern of said mold layer are adjusted by conditioning the mold, after it is released from a metal master pattern, at predetermined temperature and humidity;

placing curable molding material between said base board and said mold layer of said mold, and filling said molding material into the groove-pattern of said mold;

curing said molding material and forming a fine structure consisting of said base board and the protrusion pattern integrally connected thereto; and

removing said fine structure from said mold.

<u>Brief Description of the Drawings</u>

Fig. 1 is a sectional view schematically showing an example of conventional PDP to which the present invention can be applied.

Fig. 2 is a perspective view showing a back panel used in the PDP of Fig. 1.

Fig. 3 is a graph which plots relation between expansion of polyester film and change of relative humidity and temperature.

Fig. 4 is a perspective view showing a flexible mold according to one embodiment of the present invention.

Fig. 5 is a sectional view taken along the line V-V of the mold in Fig. 4.

Fig. 6A, 6B, and 6C are views showing sequentially a method of making a flexible mold according to the present invention.

Fig. 7 is a sectional view showing schematically a method for conditioning the flexible mold according to the present invention.

Fig. 8 is a plan view showing the dimensional change of the mold during conditioning.

Fig. 9A, 9B, and 9C are sectional views showing sequentially a method for manufacturing a back panel for PDP according to the present invention.

Fig. 10 is a graph showing the dimensional change in the total pitch of the PDP ribs.

Detailed Description

The flexible mold and the method of making same as well as the method for manufacturing a fine structure according to the present invention may be advantageously carried out, respectively, in various embodiments. Embodiments of the present invention will be described in detail below with reference to manufacture of ribs for PDP as a typical example of fine structures. It is to be understood that the present invention is by no means restricted to manufacture of ribs for PDP.

As has already been described with reference to Fig. 2, the ribs 54 for PDP are provided on the back glass substrate 51

to form a back panel for PDP. The spacing c of the ribs 54 (cell pitch) may vary depending upon the size of the screen, and is typically in the range of about 150 to 400 μm. In general, the ribs should satisfy following two requirements, that is, "there is no such defects as inclusion of air bubbles, deformation, and the like" and "the pitch of ribs has high precision." With regard to the precision of the pitch, ribs are required to be provided at the specified location with little deviation relative to address electrodes, and indeed the tolerance of position is within a few tens of μm. If the positional error exceeds a few tens of μm, light emitting condition for visible light is adversely affected, and satisfactory light emitting display cannot be expected. Since screen size has become increasingly large nowadays, the problem of the insufficient precision of the rib-pitch is serious.

When ribs 54 are considered as a whole, the required dimensional accuracy of the total pitch R of ribs 54 (distance between the ribs 54 at both ends; although only 5 ribs are shown in this figure, usually about 3000 ribs are present) is generally within a few tens ppm, although there may be some difference depending upon the size of the substrate or the shape of the ribs. In general, ribs can be advantageously formed using a flexible mold comprising a support and a mold layer with a groove-pattern supported by the support, and the total pitch of the mold (distance between groove portions at both ends) is also required to satisfy the same dimensional accuracy of a few tens ppm or less as the ribs.

In the case of conventional flexible mold, hard plastic film is used for the support and a mold layer having a groove-pattern is formed by molding of photodurable resin. The plastic film used for the support is generally a plastic raw material formed in the shape of sheet, and is commercially

available as wound on a roll. The plastic film in the form of wound roll has lost moisture in the manufacturing process, and hence contains little water and is in dried state. When a mold is made from the plastic film in dried state using a metal master pattern, the film begins to absorb moisture after the plastic film is unwound from the roll, and as a result of expansion of the film, a dimensional change takes place. This dimensional change takes place most notably immediately after the mold is released from the metal master pattern, and the magnitude of the dimensional change of the film amounts to about 300 to 500 ppm. Thus, with conventional molding method, dimensional accuracy within a few tens ppm required for a mold used for PDP cannot be achieved.

The present inventors have determined that above-mentioned dimensional change of the support film is a main cause of the dimensional change of the flexible mold, and has discovered that a flexible mold which exhibits high precision in shape and size can be obtained by forming the support from a known humidity responsive material and by conditioning the completed mold in a simple post-processing. Thus, unexpectedly, a groove-pattern can be obtained with high precision in shape and size by conditioning the flexible mold after it is released from the metal master pattern, in a condition of predetermined temperature and humidity (that is, at such temperature and humidity condition as required to properly compensate for the dimensional change of the support film) to contract or expand the support film.

Conditioning of the flexible mold can be performed rather easily. Usually, moisture content and expansion of a plastic film vary approximately in proportion to temperature and relative humidity, and the condition for conditioning the film can be easily set taking these known characteristics of the variation of a film into account. For example, in the case of

commercially available polyester film (Tetron ™), moisture content decreases approximately in proportion to the temperature rise, and increases approximately in proportion to the rise of relative humidity. Hence, as plotted in Fig. 3, expansion (%) of the polyester film can increase approximately in proportion to the rise of temperature and relative humidity. In other words, the support used in the flexible mold of the present invention is preferably formed of a humidity responsive material for which the humidity response characteristics are known or can be easily confirmed.

The apparatus used for conditioning of the flexible mold is not particularly restricted. Suitable conditioning apparatus include, for example, a thermohygrostat. In some cases, in place of above-mentioned processing in a thermohygrostat, the flexible mold may be subjected to moisture absorption processing such as water or vapor spraying, dipping in water or in warm water, passage through an atmosphere of high temperature and high relative humidity.

In addition to humidity responsive property, the support material has preferably sufficient flexibility and suitable hardness to ensure the flexibility of the mold.

With regard to the hardness of the support material, in order to control the dimensional accuracy of the groove-pitch of the flexible mold within a few tens ppm, a material which is by far harder than the molding material for forming the mold layer (preferably, a photocurable material such as a photocurable resin) responsible for forming the groove portion, is preferably selected as the material for the support. In general, contraction of a photocurable resin upon hardening is about a few percent. Thus, if a soft plastic film is used for the support, the contraction of the photocurable resin upon hardening may bring about a dimensional change of the support itself, so that the pitch accuracy of the groove portion cannot

be controlled within a few tens ppm. On the contrary, if the plastic film is sufficiently hard, the dimensional precision of the support itself can be maintained even when the photocurable resin contracts upon hardening, and hence high dimensional precision of the groove pitch can be maintained. In addition, if the plastic film is hard, the variation of pitch during fabrication of the ribs can also be kept small, leading to advantage both in molding and dimensional accuracy. Examples of hard plastic films suitable for use in implementing the present invention are listed below.

If the plastic film is hard, the pitch precision of the groove portion of the mold depends solely on the dimensional change of the plastic film, so that, in order to provide molds having desired pitch precision stably, it is sufficient to perform post-processing so as to obtain the expected dimensions of the plastic film with no change in the fabricated molds.

Hardness of the support material may be expressed as, for example rigidity to tension, or as tensile strength. Tensile strength of the material for the support is typically at least 5 kg/mm^2, and is preferably at least 10 kg/mm^2. If the tensile strength of the support material is below 5 kg/mm^2, workability is impaired in releasing the obtained mold from the metal master pattern or in removing the PDP ribs from the mold, and breakage or rupture may result.

Thus, in view of easy conditioning and excellent workability, a preferable support for implementing the present invention is a film of plastic material which is both humidity responsible and hard. Examples of suitable plastic materials include, but is not limited to, polyethylene terephthalate (PET), polyethylene naphthalate (PEN), stretched polypropylene, polycarbonate, triacetate, and the like. Among them, PET film is useful for the support, and polyester film, for example Tetron™ film, may be advantageously used for the support.

These plastic films may be used individually as a single film, or may be used in combination of two or more films as a composite film or a laminate film.

Above-mentioned plastic film or other support may be used in various thickness depending upon the construction of the mold and PDP. But, the thickness is typically in the range of about 0.05 to 1.0 mm, preferably about 0.1 to 0.4 mm. If the thickness of the support is outside of the above-mentioned range, workability or the like may be degraded. The greater the thickness of the support is, the more advantageous it is in terms of strength.

The flexible mold of the present invention includes, in addition to the above-described support, a mold layer provided on the support. The mold layer has a groove-pattern formed on the surface thereof with specified shape and size corresponding to ribs on the back panel of PDP or protrusions of other fine structure manufactured using the mold, as described in detail below. Usually, the mold layer is formed as a single layer, but may be formed in multi-layer structure of two or more materials of different properties, if necessary. When use of a photocurable molding material is specifically taken into account, both the support and the mold layer are preferably transparent.

Next, construction of the flexible mold and method for manufacturing same will be described in greater detail.

Fig. 4 is a partial perspective view showing a flexible mold according to a preferred embodiment of the present invention, and Fig. 5 is a cross-sectional view taken along the line V-V of Fig. 4. As can be seen from the figures, this flexible mold 10 is not designed for the manufacture of the glass substrate 51 for the back panel having a straight rib pattern in which a plurality of ribs 54 are arranged in parallel to each other, as shown in Fig. 2, but the flexible

mold 10 is designed for the manufacture of a glass substrate for a back panel (not shown) having a lattice rib pattern in which a plurality of ribs are arranged generally in parallel so as to cross each other at a constant spacing.

As shown in the figures, the flexible mold 10 has a groove-pattern of predetermined shape and size on its surface. The groove-pattern is a lattice pattern in which a plurality of rib portions 4 are arranged generally in parallel so as to cross each other at a constant spacing. Since the flexible mold 10 is formed with opened groove portions in lattice pattern provided on its surface, it can be advantageously used, for example, for molding of PDP ribs having protrusions in lattice pattern, although it can be applied to the manufacture of other fine structures. Although the flexible mold 10 may include additional layers as necessary, or any treatment or processing may be performed on various layers forming the mold, it is constructed basically from a support 1 and a mold layer 11 with groove portion 4 on it, as shown in Fig. 4.

The mold layer 11 is preferably formed from cured product of a curable material. The curable material is a thermosetting material or a photocurable material. The photocurable material is especially advantageous since it does not require large-size heating furnace in forming the mold layer, and can be hardened in a relatively short time period. The photocurable material is preferably a photocurable monomer or oligomer, more preferably a photocurable acryl monomer or oligomer. The curable material may contain any additives as necessary. suitable additives include, for example, a polymerization initiator (for example, a photoinitiator), an antistatic agent, etc.

Suitable acrylic monomers useful for forming the mold layer include, but are not limited to, urethane acrylate, polyether acrylate, acrylamide, acrylonitrile, acrylic acid,

acrylate ester, and the like. Suitable acrylic oligomers useful for forming the mold layer include, but are not limited to, urethane acrylate oligomer, epoxy acrylate oligomer, and the like. In particular, urethane acrylate and its oligomer can provide a flexible and strong cured product upon hardening, and moreover, can be hardened very quickly among all acrylates so that they can contribute to improvement of the productivity in producing molds. By using these acrylic monomer and oligomer, an optically transparent mold layer can be obtained. Thus, when a flexible mold having such a mold layer is used for the manufacture of PDP ribs or other fine structures, a photocurable molding material can be used. These acrylic monomers and oligomers may be used alone, or may be used in any combination of two or more of them.

As has been already described in detail, the support 1 that supports the mold layer 11 is preferably a plastic film with the thickness typically in the range of about 0.05 to 1.0 mm. The support is preferably optically transparent. If the support is optically transparent, the light irradiated for hardening can pass through this support so that photocurable molding material can be used for forming the mold layer. Examples of typical transparent support have been described above.

The flexible mold of the present invention can be manufactured using various techniques. For example, the flexible mold used for the manufacture of the substrate (back panel) for a PDP as shown in Fig. 2 can be advantageously manufactured following the steps as sequentially shown in Figs. 6 and 7.

First, as shown in Fig. 6 (A), a metal master pattern 5 having the shape and size corresponding to the substrate for PDP to be manufactured, a support 1 (hereinafter referred to as support film) formed of a transparent plastic film, and a

laminate roll 23 are provided. The metal master pattern 5 has partition walls 14 on its surface which are in the same pattern and shape as the ribs on the back panel for PDP. Thus, the spaces (concavities) 15 defined by adjoining partition walls 14 are to become the discharge cell for display in PDP. Taper may be provided on the upper end portion of the partition wall 14 in order to prevent bubble inclusion. By providing a metal master pattern which has the same form as the final ribs, the need for processing the end portions after fabrication of the ribs is eliminated, and occurrence of defects due to the debris produced by the processing of end portions can be avoided. In this manufacturing process, the whole molding material for rib fabrication is hardened and very little residue of the molding material is left on the metal master pattern so that the master pattern can be easily used again. The laminate roll 23 consists of a rubber roll, and is intended to press the support film 1 onto the metal master pattern 5. The laminate roll may be replaced by other well known or conventional laminating means, if necessary. The support film 1 consists of polyester film or other transparent plastic film as described above.

Then, well known or conventional coating means, such as a knife coater or a bar coater, are used to coat a photocurable molding material 11 to the end surface of the metal master pattern 5 in a predetermined amount. If a flexible and elastic material is used for the support film 1, even when the photocurable molding material 11 shrinks, close contact with the support film 1 can prevent the dimensional change of 10 ppm or greater, as long as the support film itself does not deform.

Preferably, aging treatment should be performed under the manufacturing environment of the mold prior to the laminating process in order to eliminate dimensional change of the support film due to humidity. Without this aging treatment, unacceptable variation (for example, variation on the order of

300 ppm) may arise in the dimensions of the obtained molds.

Next, the laminate roll 23 is slid on the metal master pattern 5 in the direction of the arrow. As a result of this laminating process, the molding material 11 is distributed in a predetermined thickness and the gap between the partition walls 14 is filled with the molding material 11.

After the laminating process has been completed, with the support film 1 laminated on the metal master pattern 5, as shown in Fig. 6 (B), the molding material 11 is irradiated with light (hv) via the support film 1 as shown by the arrow. If the support film 1 does not include any light scattering elements such as air bubbles, and is formed uniformly of transparent material, the irradiated light is hardly attenuated and can reach to the molding material 11 uniformly. As a result, the molding material is effectively hardened to form uniform molding layer 11 adhered to the support film 1. Thus, the support film 1 and the molding layer 11 are integrally joined together to provide a flexible mold. In this manufacturing process, UV light with wavelength in the range of 350 to 450 nm can be used, and therefore, there is an advantage that a high pressure mercury lamp such as a fusion lamp that is a highly heat-generating light source needs not be used. Since the support film and the mold layer are not deformed by heat at the time of hardening with light, there is an additional advantage that the pitch can be controlled in high precision.

Then, as shown in Fig. 6(C), the flexible mold 10 is released without impairing its integrity from the metal master pattern 5.

Next, as shown in Fig. 7, the flexible mold 10 is placed in a thermohygrostat 15 and is subjected to a conditioning process following a predetermined schedule. The condition for the conditioning may be modified in accordance with the level

of dimension adjustment desired for the mold. If, as a result of this processing, relative humidity in the thermohygrostat 15 is decreased, for example, the overall size of the mold 10 is reduced, and hence the total pitch M is also decreased, as shown schematically in Fig. 8. On the contrary, if relative humidity is increased, the overall size of the mold 10 is expanded, and hence the total pitch M is increased.

The flexible mold of the present invention can be manufactured relatively simply, irrespective of the size and dimensions, as long as suitable well known and conventional laminating means and coating means are employed. Thus, in accordance with the present invention, in contrast to the conventional manufacturing process using vacuum equipment such as vacuum press molding machine etc., a large-size flexible mold can be manufactured simply and easily with no limitation.

Moreover, the flexible mold of the present invention is useful in the manufacture of various fine structures. For example, the flexible mold of the invention is useful for molding of ribs for PDP with straight rib pattern or lattice rib pattern. Thus, by using the flexible mold, a large screen size PDP with rib structure that does not permit leakage of UV light from discharge cells for display can be easily manufactured simply by employing a laminate roll in place of vacuum equipment and/or complicated process.

The present invention is also directed to a manufacturing process for manufacturing fine structures using the flexible mold of the invention. The fine structure may have various structures, and is typically exemplified by a substrate (back panel) for PDPs which is provided with ribs on a glass plate. The manufacturing process of a substrate for PDP as shown in Fig. 2 will be described below with reference to Fig. 9. A manufacturing equipment as shown in Figs. 1 to 3 of Japanese Unexamined Patent Publication (Kokai) No. 2001-191345, for

example, can be advantageously used in implementing this process.

First, a glass plate is provided with electrodes arranged in parallel to each other at a constant spacing, and is set on a surface plate. Then, as shown in Fig. 9(A), the flexible mold 10 of the present invention is placed at specified position on the glass plate 31, and the glass plate 31 and the mold 10 are suitably aligned with each other. Since the mold 10 is optically transparent, the alignment with the electrodes on the glass plate 31 can be carried out easily. More specifically, the alignment may be performed visually, or by using a sensor such as a CCD camera, such that the groove portions of the mold 10 are set in parallel to the electrodes on the glass plate 31. If necessary, temperature and humidity may be adjusted to bring the groove portions into coincidence with the separation between adjoining electrodes on the glass plate 31. This adjustment is required because the mold 10 and the glass plate 31 expands or contracts to different extent in accordance with change of temperature and humidity. Therefore, after the alignment of the glass plate 31 with the mold 10 has been completed, temperature and humidity need to be controlled so as to remain constant. This control method is especially effective in the manufacture of a large area substrate for PDP.

Then, a laminate roll 23 is placed on an end portion of the mold 10. The laminate roll 23 is preferably a rubber roll. Here, the one end portion of the mold 10 is preferably fixed on the glass plate 31, so that displacement of the mold 10 with respect to the glass plate 31 may be avoided after the alignment has been completed.

Next, the other free end portion of the mold 10 is raised by a holder (not shown) above the laminate roll 23 to expose the glass plate 31. At this time, the mold 10 should not be subjected to tension. This is for preventing the mold 10 from

being wrinkled and for maintaining the alignment of the mold 10 with the glass plate 31. Other means may be employed as long as the alignment can be maintained. In the present manufacturing process, since the mold 10 has elasticity, the mold 10 can be restored at the time of laminating process, accurately to the initial position of the alignment after it has been raised as shown in the figure.

Then, specified amount of rib precursor 33 required to form ribs is supplied onto the glass plate 31. The rib precursor can be supplied using, for example, a hopper with nozzle for paste.

As used herein, the term "rib precursor" means any molding material which can be formed into the rib molding as the intended end product, and there is no special limitation as long as the rib molding can be formed. The rib precursor may be thermo-setting or photocurable. In particular, a photocurable rib precursor can be used very effectively in combination with the above-described transparent flexible mold. As described above, the flexible mold rarely includes air bubbles or defects such as deformations, and can suppress uneven scattering of light. Therefore, the molding material is hardened uniformly to form ribs of constant and good quality.

An example of composition suitable for the rib precursor is a composition basically including: (1) a ceramic component for giving the shape of the ribs, such as aluminum oxide; (2) a glass component for filling the gap between the ceramic component and adding density to the ribs, such as lead glass or phosphate glass; and (3) a binder and its hardener for containing, holding and binding ceramic component with each other or polymerization initiator. Hardening of the binder component is preferably achieved not by heating or warming, but by irradiation with light, since thermal deformation of the glass plate no longer needs to be considered in this case. If

necessary, in order to lower the temperature for removing the binder component, an oxidation catalyst consisting of oxides, salts or complexes of chromium (Cr), manganese (Mn), iron (Fe), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), indium (In) or tin (Sn), ruthenium (Ru), rhodium (Rh), palladium (Pd), silver (Ag), iridium (Ir), platinum (Pt), gold (Au) or cerium (Ce) may be added to the composition.

In the practice of the illustrated manufacturing process, the rib precursor 33 is not supplied uniformly to the entire glass plate 31. As shown in Fig. 9(A), the rib precursor 33 has only to be supplied to the portion of the glass plate 31 near the laminate roll 23, since, in the step described later, the laminate roll 23 is moved on the mold 10 so as to spread the rib precursor 33 uniformly on the entire glass plate 31. In this case, it is desirable that the rib precursor 33 has viscosity typically about 20,000 cps or less, preferably about 5,000 cps or less. If the viscosity of the rib precursor is higher than about 20,000 cps, it is difficult to spread the rib precursor sufficiently with the laminate roll, and as a result, air may be entrained into the groove portion of the mold, and may become a cause of defects of the ribs. In fact, if the viscosity of the rib precursor is about 20,000 cps or less, the laminate roll needs to be moved from one end of the glass plate to the other end only once for spreading the rib precursor uniformly between the glass plate and the mold and filling all groove portions uniformly without giving rise to inclusion of air bubbles. Method of supplying the rib precursor is not restricted to the above-described method. For example, the rib precursor may be coated to the entire surface of the glass plate, although this is not shown. In this case, the rib precursor for coating has the same viscosity as described above. In particular, when ribs in the shape of a lattice pattern are to be formed, the viscosity of the rib precursor is

typically about 20,000 cps or less, preferably 5,000 cps or less.

Next, a rotary motor (not shown) is driven to move the laminate roll 23 on the mold 10 as shown by the arrow in Fig. 9(A). While the laminate roll 23 is thus moved on the mold 10, pressure is applied to the mold 10 successively from one end portion to the other end portion by the dead weight of the laminate roll 23 so that the rib precursor 33 is spread between the glass plate 31 and the mold 10 and is filled into the groove portion of the mold 10. Thus, the rib precursor successively replaces air in the groove portion and is filled into it. The rib precursor may be spread in the thickness in the range of a few μm to a few tens μm by suitably controlling the viscosity of the rib precursor, and the diameter, weight or moving speed of the laminate roll.

With the illustrated manufacturing process, the groove portion of the mold also acts as a channel for air so that, even if air is captured in the groove, the air can be efficiently discharged through this channel out of the mold to surroundings when pressure is applied as described above. Consequently, the present manufacturing process can prevent inclusion of remaining air bubbles even if the rib precursor is filled under atmospheric pressure. In other words, reduced pressure needs not be applied in filling the rib precursor. It is to be understood that reduced pressure may be utilized to further facilitate removal of air bubbles.

Then, the rib precursor is hardened. If the rib precursor 33 spread on the glass plate 31 is photocurable, the laminate consisting of the glass plate 31 and the mold 10 is placed in a irradiation apparatus (not shown), and the rib precursor 33 is irradiated with light such as ultraviolet ray (UV) via the glass plate 31 and the mold 10, as shown in Fig. 9(B). After

hardening, a molded product of the rib precursor, that is, the rib per se is obtained.

Finally, with the obtained rib 34 adhered to the glass plate 31, the glass plate 31 and the mold 10 are removed from the irradiation apparatus, and the mold 10 is separated and removed, as shown in Fig. 9(C). Since the mold 10 of the present invention is excellent in ease of handling, if a material of low adhesion is used as coating layer of the mold, the mold 10 can be easily separated and removed with small force without damaging the rib 34 adhered to the glass plate 31. It should be appreciated that no large scale apparatus is required for the separation and removal of the mold.

[Examples]

The present invention will now be described more specifically with reference to the following examples. It should be easily understood by those skilled in the art that the present invention is by no means restricted to the examples.

Production of the flexible mold

For the manufacture of back panel for PDP, a rectangular metal master pattern having ribs (partition walls) in a straight pattern was prepared. More specifically, the metal master pattern had ribs with the cross section along the longitudinal direction in the shape of isosceles trapezoid arranged at a constant pitch. The space (concavity) defined by adjoining ribs corresponds to a discharge cell for display for PDP. Each of the ribs was 135 µm in height, 60µm in top width, and 120 µm in bottom width. Pitch (distance between the centers of adjoining ribs) was 300 µm, and number of ribs was 3000. Total pitch (distance between the centers of ribs at both ends) was 900.221 µm.

In order to use in forming the mold layer of the mold, a

photocurable resin was prepared by mixing 99 weight % of aliphatic urethane acrylate oligomer (manufactured by Daicel-UCB, Co.) and 1 weight % of 2-hydroxy-2-methyl-1-phenyl-propane-1-one (Trade name "Darocure 1173"; manufactured by Chiba Speciality chemicals, Co.).

In order to use as the support for the mold, PET film of 1300 mm in width and 1.88 μm in thickness wound on a roll (Trade name, "HPE188"; manufactured by Teijin Co.) was provided.

Then, the above-described photocurable resin was coated in the shape of a line to the upstream end of the prepared metal master pattern. Then, above-described PET film was laminated on the surface of the metal master pattern so as to cover it. When a laminate roll was used carefully to press the PET film, the photocurable resin was filled into the concavities of the metal master pattern.

In this state, the photocurable resin was irradiated via the PET film using a fluorescent lamp (manufactured by Mitsubishi-Osram Co.) with light having wavelength of 300 to 400 nm 30 seconds. The photocurable resin was hardened and the mold layer was thus obtained. Then the PET film together with the mold layer was released from the metal master pattern, and thus a flexible mold having a multiplicity of groove portion of shape and size corresponding to the rib on the metal master pattern. Then, the mold was placed in a thermohygrostat at temperature of 22 °C and relative humidity (RH) of 40%, 50%, 55%, or 60%, and was allowed to be subjected to conditioning for 12 hours.

After conditioning, total pitch of the mold was measured and the measurement result as plotted with white circles M in Fig. 10 was obtained.

Production of a back panel for PDP

After the flexible mold was produced as described above, the mold was arranged in alignment to a glass substrate for PDP. The mold was placed with the groove-pattern facing the glass substrate. Then, photosensitive ceramic paste was filled between the mold and the glass substrate. The ceramic paste used had following composition.

· photocurable oligomer: dimethacrylate of bisphenol-A-diglycidyl ether (manufactured by Kyoeisya Chemical Co.) 21.0 g

photocurable monomer: triethyleneglycol dimethacrylate (manufactured by Wako Pure Chemicals Industries, Co.) 9.0 g

diluent: 1,3-butanediol (manufactured by Wako Pure Chemical Industries, Co.) 30.0 g

photoinitiator: bis(2,4,6-trimethylbenzoyl)-phenyl phosphine oxide (Trade name "Irgacure" : manufactured by Chiba Speciality Chemicals, Co.) 0.3 g

surfactant: phosphate propoxyalkyl polyol 3.0 g

inorganic particle: mixed powder of lead glass frit and ceramic particles (manufactured by Asahi Glass, Co.) 180.0 g

After the ceramic paste has been filled, the mold was laminated so as to cover the surface of the glass substrate. When laminate roll was used carefully to press the mold against the substrate, the ceramic paste was completely filled into the groove portion of the mold.

In this state, a fluorescent lamp (manufactured by Philips Co.) was used to irradiate the ceramic paste with light having wavelength of 400 to 450 nm for 30 seconds from both sides via the mold and the glass substrate. The ceramic paste was hardened to form the ribs. Then, the glass substrate together with the ribs formed thereon was separated from the mold, and a back panel for PDP consisting of the glass substrate with ribs

formed thereon was obtained as intended. Total pitch of the ribs was measured immediately after separation from the mold for each back panel, and the measurement result as plotted with black circles R in Fig. 10 was obtained. The curve I of Fig. 10 shows the tendency of the variation of total pitch of ribs.

As can be seen from the measurement result shown in Fig. 10, the total pitch of ribs for PDP obtained, for example, for conditioning performed at 22 °C and 50% RH, was 900.221 mm (average of seven points), while the total pitch of ribs for PDP obtained for RH increased by 10% from 50%, that is, at 60% RH, was 900.291 mm (average of seven points). Thus, by increasing RH, the total pitch of ribs for PDP can be increased by 78 ppm compared to the previous value at 50% RH. In other words, the total pitch can be increased at a rate of 7.8 ppm/% increase of RH.

When condition for conditioning of the mold was changed from 22 °C and 50% RH to 22 °C and 40% RH, the obtained total pitch of ribs for PDP was 900.173 mm (average of seven points). Thus, compared to the previous condition of 22 °C and 60% RH, by decreasing RH by 20%, the total pitch can be decreased by 131 ppm. In other words, the total pitch can be decreased at a rate of 6.6 ppm/% decrease of RH.

As has been described in the foregoing, in accordance with the present invention, a flexible mold can be provided which is useful in manufacturing ribs for PDP or other fine structures, and which permits protrusions such as ribs to be formed at specified position easily and accurately with high dimensional precision and without requiring high skill of workers.

In accordance with the present invention, a flexible mold can be provided which permits ribs for PDP or other fine structures to be manufactured in high precision without giving rise to air bubbles, deformation of pattern, or other defects.

Further, in accordance with the present invention, a

flexible mold for manufacturing ribs for PDP or other fine structures can be manufactured in high precision without requiring high skill.

Also in accordance with the present invention, ribs for PDP, for example, or other fine ceramic structures can be easily manufactured using the flexible mold of the invention at low cost, in short time, and with high precision.

Claims

1. A flexible mold comprising:

a support formed of humidity responsive material; and

a mold layer provided on said support and having a groove-pattern of specified shape and size formed on the surface thereof;

characterized in that said specified shape and size are given to said groove-pattern by conditioning said mold under a predetermined condition of temperature and humidity after it is released from a metal master pattern.

2. A flexible mold according to claim 1, wherein said support and said mold layer are transparent.

3. A flexible mold according to claim 1 or 2, wherein said support is a film of humidity responsive plastic material.

4. A flexible mold according to claim 3, wherein said plastic material is at least one plastic material selected from the group consisting of polyethylene terephthalate, polyethylene naphthalate, stretched polypropylene, polycarbonate, and triacetate.

5. A flexible mold according to any one of claims 1 to 4, wherein said support has a thickness in the range of 0.05 to 1.0 mm.

6. A flexible mold according to any one of claims 1 to 5, wherein said mold layer is formed of cured product of a curable material.

7. A flexible mold according to claim 6, wherein said curable material is a photocurable monomer and/or oligomer.

8. A flexible mold according to claim 7, wherein said photocurable monomer and/or oligomer is acrylic monomer and/or oligomer.

9. A flexible mold according to claim 8, wherein said acrylic monomer and/or oligomer is selected from the group consisting of urethane acrylate, polyester acrylate, and polyether acrylate.

10. A flexible mold according to any one of claims 1 to 9, wherein said groove-pattern of the mold layer is a straight pattern composed of a plurality of groove portions arranged generally in parallel to each other at a constant spacing.

11. A flexible mold according to any one of claims 1 to 9, wherein said groove-pattern of the mold layer is a lattice pattern composed of a plurality of groove portions arranged generally in parallel and crossing with each other at a constant spacing.

12. A method of making a flexible mold having a support and a mold layer which is provided on said support and has a groove-pattern of specified shape and size formed on the surface thereof, said method comprising the steps of:

forming a layer of photocurable material by coating a photocurable material at a predetermined film thickness on a metal master pattern having a protrusion-pattern formed on the surface thereof in shape and size corresponding to said groove-pattern of the mold;

laminating a transparent support of humidity responsive plastic film on said metal master pattern to thereby form a laminate composed of said metal master pattern, said layer of photocurable material and said support;

irradiating said laminate with light from the side of the support to cure said layer of photocurable material;

releasing from said metal master pattern said mold layer formed by curing of said layer of photocurable material together with said support; and

conditioning the obtained mold under a predetermined condition of temperature and humidity to adjust shape and size of the groove-pattern on said mold layer.

13. A method of making a flexible mold according to claim 12, wherein said plastic material of said support is at least one plastic material selected from the group consisting of polyethylene terephthalate, polyethylene naphthalate, stretched polypropylene, polycarbonate, and triacetate.

14. A method of making a flexible mold according to claim 13, wherein said photocurable material is photocurable monomer and/or oligomer.

15. A method of making a flexible mold according to claim 14, wherein said photocurable monomer and/or oligomer is acrylic monomer and/or oligomer.

16. A method of making a flexible mold according to claim 15, wherein said acrylic monomer and/or oligomer is selected from the group consisting of urethane acrylate, polyester acrylate, and polyether acrylate.

17. A method of manufacturing a fine structure having a protrusion pattern of specified shape and size on the surface of a substrate, comprising the steps of:

providing a flexible mold which comprises a support formed of a humidity responsive material and a mold layer provided on said support and having a groove-pattern of shape and size

corresponding to said protrusion pattern formed on the surface thereof, and in which the shape and size of said groove-pattern of said mold layer are adjusted by conditioning the mold under a condition of predetermined temperature and humidity after it is released from a metal master pattern;

placing curable molding material between said substrate and said mold layer of said mold, and filling said molding material into the groove-pattern of said mold;

curing said molding material and forming a fine structure consisting of said substrate and the protrusion pattern integrally connected thereto; and

releasing said fine structure from said mold.

18. A method of manufacturing a fine structure according to claim 17, wherein said mold is made by a method according to any one of claims 12 to 16.

19. A method of manufacturing a fine structure according to claim 17 or 18, wherein said curable molding material is a photocurable material.

20. A method of manufacturing a fine structure according to any one of claims 17 to 19, wherein said fine structure is a back panel of a plasma display panel.

21. A method of manufacturing a fine structure according to claim 20, further comprising the step of providing a set of address electrodes at a constant spacing on the surface of said substrate generally in parallel and independently.

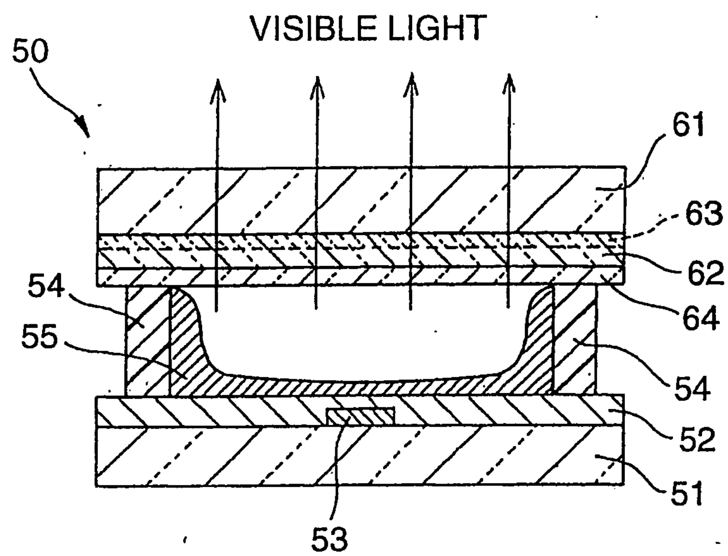


Fig. 1

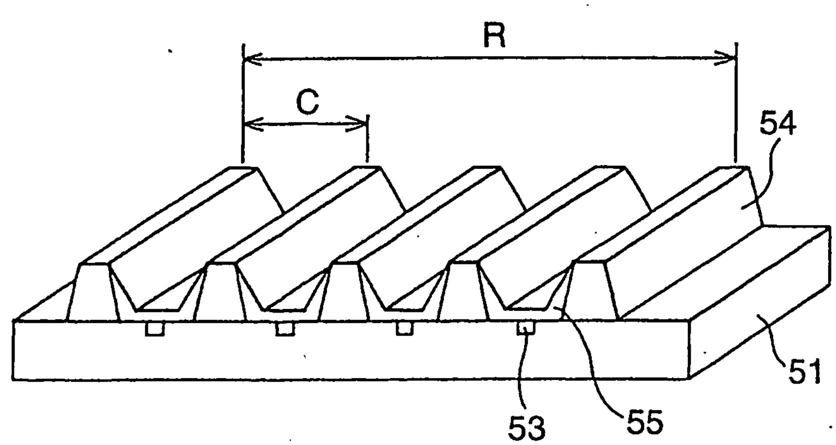
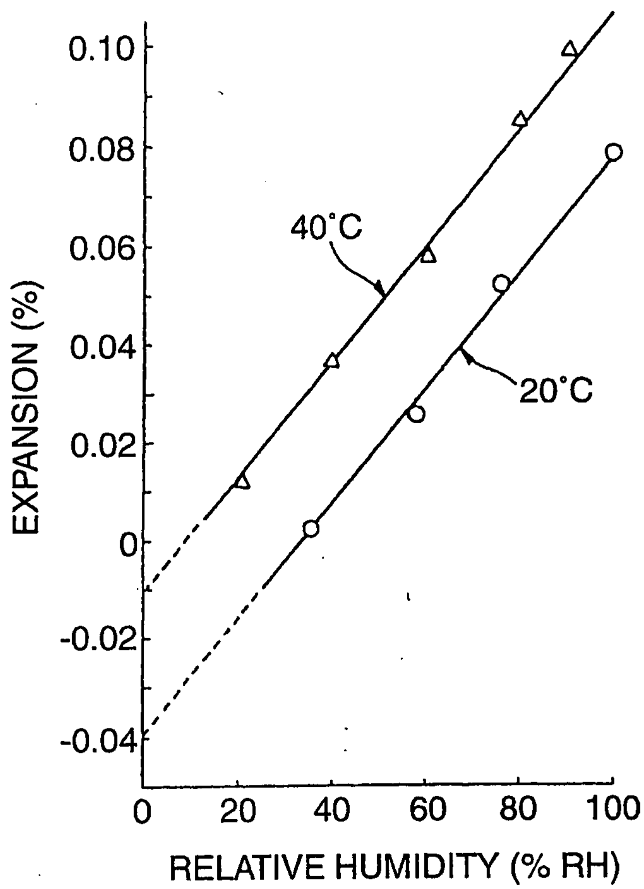


Fig. 2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0.06
0.04
0.02
0
-0.02
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20
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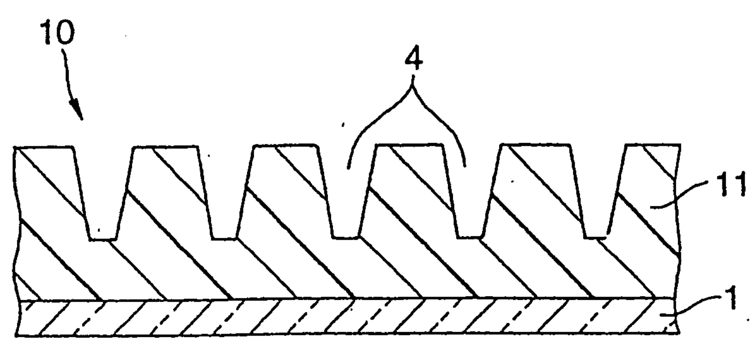
60
80
100
RELATIVE HUMIDITY (% RH)

Fig. 3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4
11
1

Fig. 5

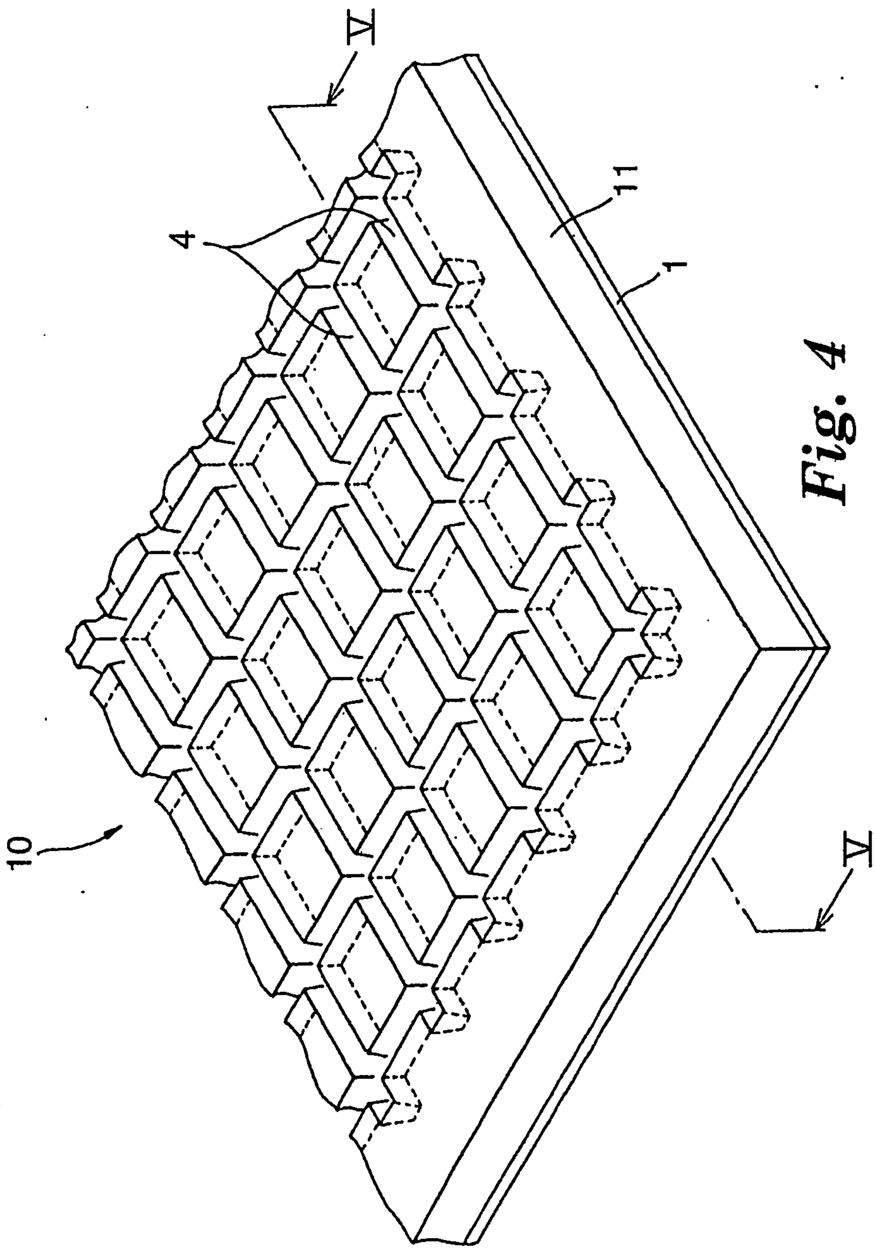


Fig. 4

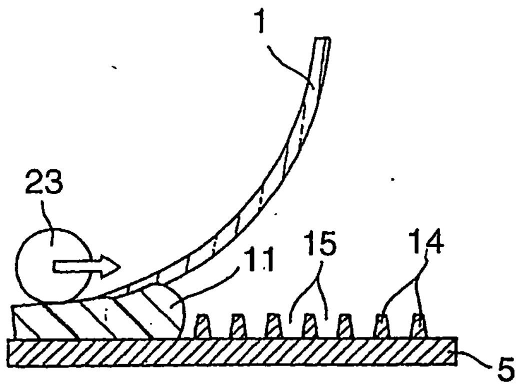


Fig. 6A

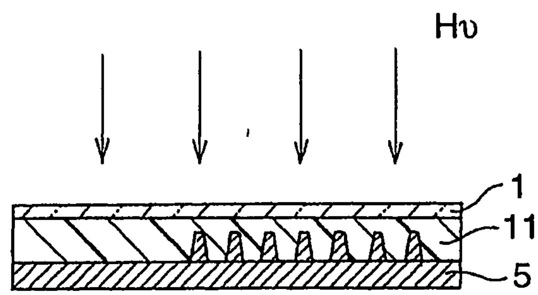


Fig. 6B

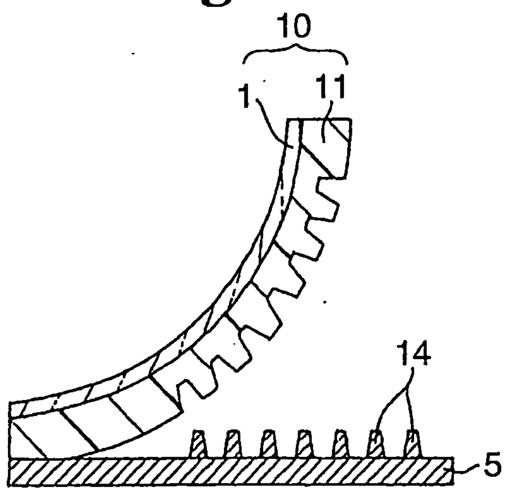


Fig. 6C

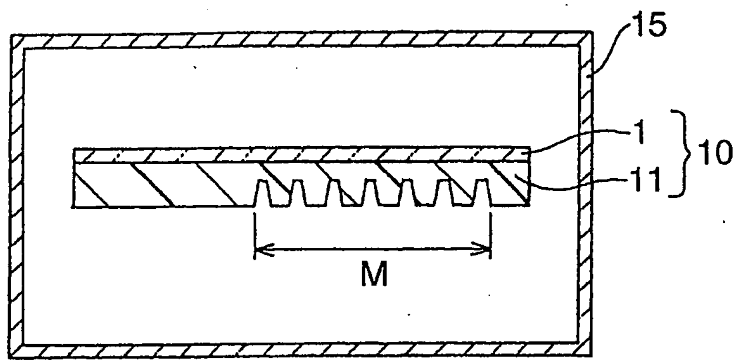


Fig. 7

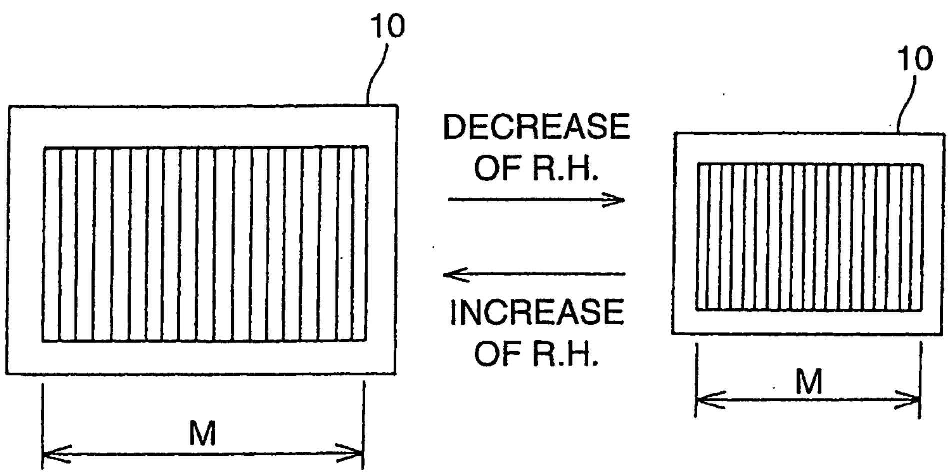


Fig. 8

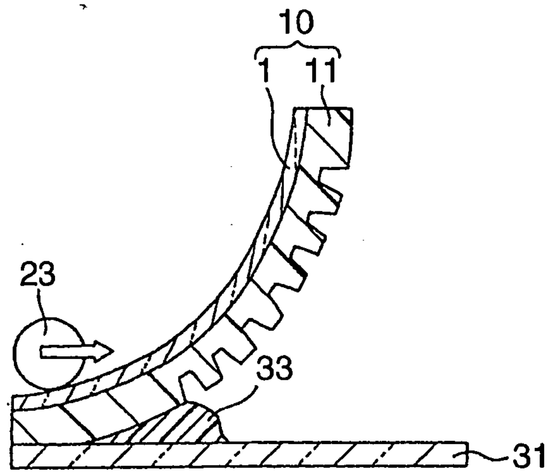


Fig. 9A

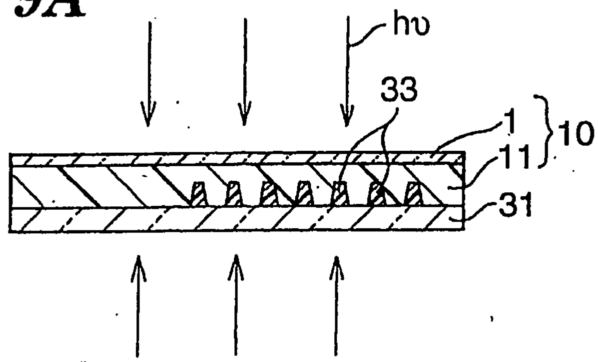


Fig. 9B

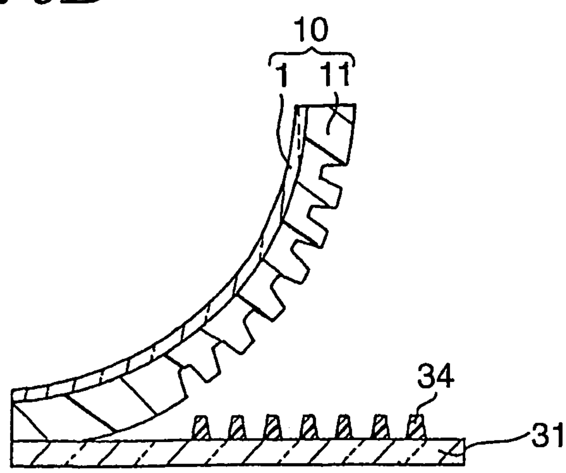
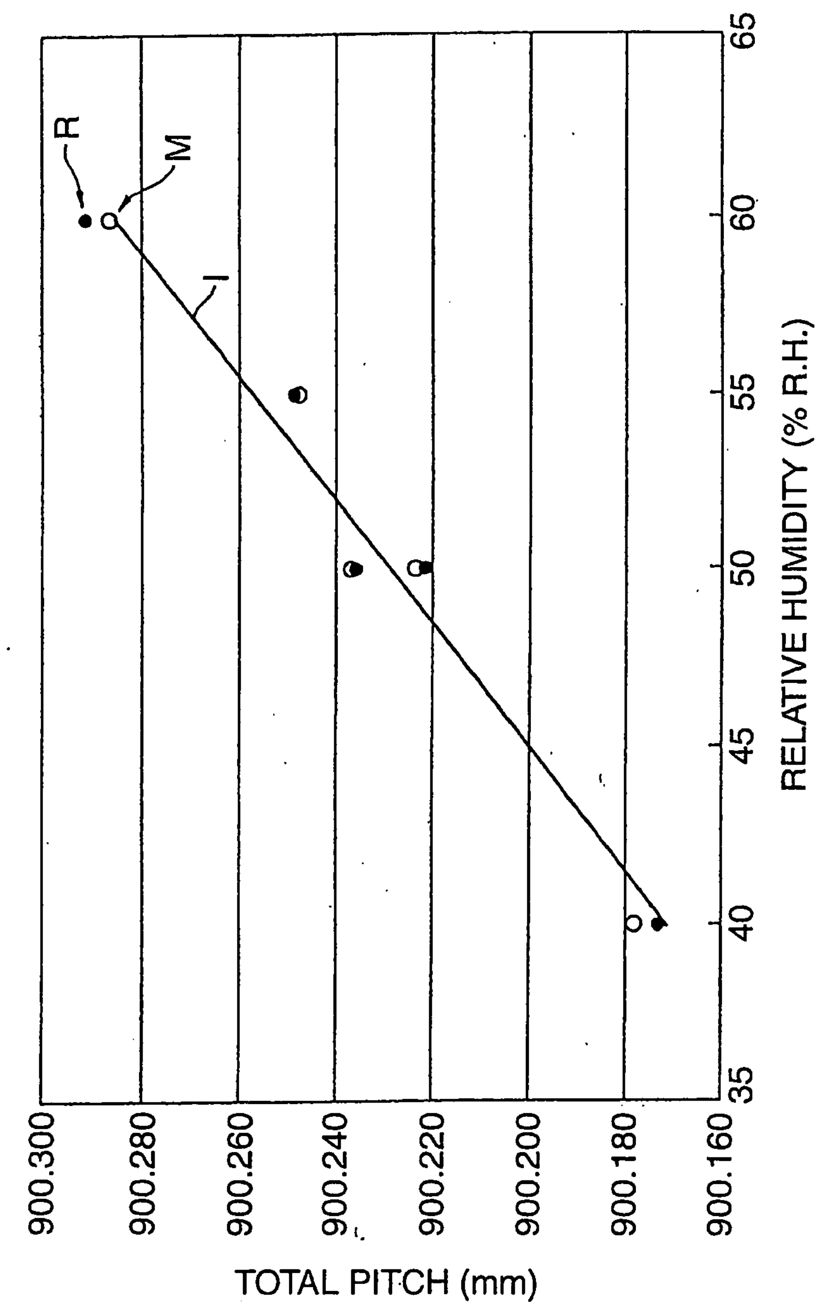


Fig. 9C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900.200
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RELATIVE HUMIDITY (% R.H.)
35
40
45
50
55
60
65
R
M
I

Fig. 10

INTERNATIONAL SEARCH REPORT

Internatio[redacted]Application No
PCT/US 03/33201

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B29C33/42

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B29C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 01/52299 A (KIKUCHI HIROSHI ; SUGIMOTO TAKAKI (JP); SUWA TOSHIHIRO (JP); YODA AKIR) 19 July 2001 (2001-07-19) abstract; p. 6, l. 4-17; p. 10, l. 15-19; p. 15, l. 24-25; p. 16, l.15-24	1-21

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 March 2004	17/03/2004

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Brunswick, A

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 03/33201

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
WO 0152299	A	19-07-2001	JP	2001191345	A	17-07-2001
			AU	3441501	A	24-07-2001
			EP	1254476	A1	06-11-2002
			WO	0152299	A2	19-07-2001
			US	2003022585	A1	30-01-2003